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Sands Reservoir
Dams, Hill County,
Montana, North
Dam, MT-3668, East
Dike, MT-3773

- INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

22

SANDS RESERVOIR DAMS

HILL COUNTY, MONTANA
NORTH DAM MT-3668 EAST DIKE MT-3773

PREPARED FOR:

HONORABLE TED SCHWINDEN

GOVERNOR, STATE OF MONTANA

AND

HAVRE IRRIGATION COMPANY

OWNER / OPERATOR

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PREPARED BY:

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Bozeman, Montana

Assisted By:

Northern Testing Labs, Inc.

Great Falls, Montana

JULY 1981

Seattle District

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TABLE OF CONTENTS

Paragraph		
	Executive Summary	i
	Pertinent Data	iv
CHAPTER 1 -	BACKGROUND	1
1.1	INTRODUCTION	1
1.1.1	Authority and Scope	1
1.1.2	Purpose	2
1.1.3	Inspection	2
1.2	DESCRIPTION OF PROJECT	3
1.2.1	General	3
1.2.2	Regional Geology	4
1.2.3	Seismicity	4
1.2.4	Site Geology	4
1.2.5	Design and Construction History	5
CHAPTER 2 -	INSPECTION AND RECORDS EVALUATION	6
2.1	HYDRAULICS AND STRUCTURES	6
2.1.1	Spillway	6
2.1.2	Outlet Works	7
2.1.3	Freeboard	7
2.2	HYDROLOGY	7
2.2.1	Physiography and Climatology	7
2.2.2	Reservoir Storage and Spillway Discharge	7
2.2.3	Estimated Probable Maximum Flood	8
2.2.4	Flood Routing	8
2.3	GEOTECHNICAL EVALUATION	9
2.3.1	North Dam Embankment	9
2.3.2	Foundation Conditions, Seepage and Drainage	10
2.3.3	Stability	11
2.4	PROJECT OPERATIONS AND MAINTENANCE	11
2.4.1	Dam Maintenance Plan	11
2.4.2	Reservoir	11
2.4.3	Warning Plan	11
CHAPTER 3 -	FINDINGS AND RECOMMENDATIONS	12
3.1	FINDINGS	12
3.1.1	Size, Hazard Classification, and Safety Evaluation	12
3.1.2	Spillways	12
3.1.3	Outlet Works	13
3.1.4	Reservoir Storage and Discharge Capacity	13
3.1.5	Dam Embankments	13
3.1.6	Stability	14
3.1.7	Operations and Maintenance	14
3.2	RECOMMENDATIONS	14
REFERENCES		16
APPENDIX A		

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PHOTOS

Photo 1 Sands Reservoir Looking Northeast

Photo 2 North (Main) Dam Crest

Photo 3 Erosion Bench on Upstream Slope of North Dam

Photo 4 Principal Outlet Works Gate Controls

Photo 5 Downstream Face North Dam

Photo 6 Area Downstream of North Dam

Photo 7 Wide Crest Section on East Dike

Photo 8 Looking Downstream from Irrigation Outlet Culvert on East Dike

Photo 9 Minimum Width Crest Section on East Dike

Photo 10 Typical East Dike Crest Section

Photo 11 Localized Wet Areas Along Downstream Toe of East Dike

Photo 12 Spillway Channel

Photo 13 Diversion Channel ¼ Mile Upstream Looking Due South

PLATES

Plate 1 Location Map

Plate 2 Drainage Map

Plate 3 Site Plan

Plate 4 Dam Sections

Plate 5 Outlet Works on Dam

Plate 6 Outlet Works on Dike

Plate 7 Spillway

Plate 8 Rating Curve

EXECUTIVE SUMMARY

Personnel of Christian, Spring, Sielbach & Associates, principal contractor, and Northern Testing Laboratories, Inc., subcontractors, under a contract with the Montana Department of Natural Resources and Conservation (MDNRC) and with representation from the MDNRC and the owner, inspected the Sands Reservoir Dam and Dike on December 17, 1980, under the authority of Public Law 92-367. The project is located in Sec. 18, T32N, R16E, and Sec. 13, T32N, R15E, MPM, offstream of Bullhook Creek in Hill County, Montana, approximately ½ mile south of the city of Havre, Montana.

This report was compiled from information obtained during the onsite inspection and analysis of hydrologic information. Findings were compared with engineering criteria that are currently accepted by most private and public agencies engaged in dam design, construction and operation.

Findings and Evaluation

The Sands Reservoir Dam and Dike were constructed in about 1911. There are no available records of the engineering entity responsible for design and construction nor are construction plans available. The project is primarily used for storage of irrigation waters and is owned and operated by the Havre Irrigation Company.

The 11-foot-high Sands Dam and the 7-foot-high Sands Dike impound approximately 850 acre-feet of water at minimum dam crest elevation 2635.1 feet National Geodetic Vertical Datum (NGVD). All elevations are relative to the reservoir water surface assumed elevation 2630.0 feet NGVD taken during the inspection. On the basis of criteria in the U.S. Army Corps of Engineers Recommended Guidelines for Safety Inspection of Dams (Ref. 6), the project is small in size.

The sudden failure of either Sands Dam or Dike would cause flooding in the town of Havre located about ½ mile downstream of the dam. Several residences, and a large mobile home court located at the downstream toe of the Dike could be severely damaged and there is a potential for loss of life. The conclusions on probable damage are based on a brief field visit and engineering judgment. No dam breach analysis or routing of a dam breach flood was made for the dam. In accordance with inspection guidelines, the project is classified as having a high (Category 1) downstream hazard potential.

Inspection criteria (Ref. 6) recommend that a small size project with a high downstream hazard potential be capable of safely handling ½ the probable maximum flood (PMF) to the full PMF. The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region. Because of the assessed downstream hazard potential, we recommend that the project safely handle a spillway design flood equal to the full PMF. The estimated PMF for the 150 acre drainage basin resulted from a 72-hour general storm probable maximum precipitation (PMP) developed for this dam safety study. The resultant PMF plus a diversion channel flow of 50 c.f.s. netted an

estimated volume of 592 acre-feet. The estimated maximum capacity of the spillway and principal outlet works in the North Dam is 126 c.f.s. Routing of the estimated PMF was started with the reservoir surface at the primary spillway crest elevation 2632.7 feet NGVD at the onset of the PMF. With these conditions, the routings show that the reservoir surcharge storage and spillway discharge is adequate to control the PMF. The project is very sensitive to the quantity of water that may enter the reservoir through the diversion channel from Beaver Creek during the routing of the PMF. Due to breaches of the diversion channel upstream from the project it is not possible to accurately determine potential channel flows that would result from diffused surface runoff that could enter the channel from the upstream drainage area during a significant storm event. In addition, the potential exists for raising reservoir levels above 2632.7 feet by installing flashboards (stop logs) in the primary spillway. The maximum water surface that can be controlled by the stop logs is at elevation 2634.2 feet NGVD. The dams are constructed of materials that could erode and fail when overtopped by flood water.

The visual inspection revealed no signs of cracking or unusual settlement in the dam embankments. The upstream slope of both embankments has some wave erosion damage. Roots of trees and shrubs in the upstream slope provide potential seepage paths under prolonged high reservoir elevations. No substantial seepage was apparent at the foundation-embankment contact of the downstream toe of the dam or the dike. However, downstream toe areas were wet, possibly the combined result of underflow and natural groundwater.

There is insufficient data on seepage, position of the phreatic surface, and strength of embankment and foundation materials to accurately assess the stability of the embankment. However, present operating conditions and past service indicate dam stability to be adequate. Should operating conditions change allowing development of steady state seepage conditions under prolonged higher than normal pool elevation, the likely development of preferential seepage paths could lead to erosion and possible sloughing of the downstream slopes particularly in sections of the East Dike that have been weakened by wave erosion.

Reservoir discharges are through 3 outlets: an unlined earthen primary spillway, containing a concrete weir structure capable of controlling reservoir levels in a range of 1.5 feet, and a well grassed emergency spillway both located on the southeast rim of the reservoir; an 18-inch diameter CMP irrigation outlet works in the North Dam; and an 8-inch diameter irrigation pipe in the East Dike. Both conduits are controlled by gates at or near the inlet. Because of the reservoir level at the time of inspection and the small size of the principal outlet works and the irrigation outlet conduits, a complete inspection of outlet pipes could not be made.

Because the project is very sensitive to the, as yet, undetermined diversion channel flows that could occur during the routing of a significant storm event producing high runoff and the potential exists for development of higher than normal steady state seepage conditions which could cause localized erosion and sloughing on the downstream embankment slopes, it is our judgment that Sands Reservoir Dam and Dike may not conform to the recommended guidelines. More detailed hydrologic and hydraulic routing

studies are needed to better define the magnitude of the spillway design flood (SDF) and to more accurately assess diversion channel flows that could occur during the routing of a significant runoff producing event. With the remote possibility that reservoir levels could be raised and maintained at above normal operating levels for a prolonged period of time a stability analysis of embankments performance under these loading conditions should be made and placed on file.

Recommendations

Due to storage between normal pool and dam crest, the present project provides a degree of flood protection to the downstream area. The intent of the report recommendations is to maintain or improve project safety without decreasing this existing flood protection.

Develop, test and place into action a downstream warning plan for use in the event of impending dam distress. Inspect the principal and the irrigation outlet conduits, gates and lifts, and repair as required. Repair wave erosion damage on the upstream slopes and provide effective, durable riprap to protect embankments against wave erosion. Conduct more detailed hydrologic and hydraulic routing studies to better determine the diversion channel flows that could occur during routing of the SDF and the required spillway capacity to provide for it's safe passage. Modify the project as studies indicate. Have a qualified geotechnical engineer evaluate the dam for stability and seepage under possible maximum loading conditions with respect to Recommended Guideline criteria. Modify the dam embankments and provide seepage control as studies indicate. Provide for inspection by qualified engineers at least every 5 years.

Prior to performing engineering studies and remedial construction, coordinate the work with the State of Montana Department of Natural Resources and Conservation to insure compliance with all pertinent laws and regulations.

Bob B. Gemmell, P.E.

PERTINENT DATA

1.	**General**	
	Federal ID No.	North Dam MT-3668 East Dike MT-3773
	Owner/Operator	Havre Irrigation Company
	Date Constructed	1911
	Purpose	Irrigation
	Location	Sec. 18, T32N, R16E, and Sec. 13, T32N, R15E, MPM
	County, State	Hill, Montana
	USGS Quadrangle	Havre
	Watershed	Offstream of Bullhook Creek
	Downstream Hazard Potential	Category 1, High
	Size Classification	Small
2.	**Reservoir**	
	Normal Pool Elevation (Primary Spillway Crest)	2632.7 feet NGVD
	Surface Area at Normal Pool	Est. 100 acres
	Drainage Area (including reservoir)	150 acres
	Storage at Normal Pool	600 acre-feet
	Storage at Minimum Dam Crest El. 2635.1 feet NGVD	850 acre-feet
	Surcharge Storage	250 acre-feet
3a.	**Primary Spillway**	
	Type	Concrete Box structure located in Emergency Spillway for low flow control. Controlled by flash boards.
	Crest Elevation	2632.7 feet NGVD
	Crest Width	6 feet
	Capacity with Reservoir at top of structure El. 2634.2 feet NGVD	Approx. 10 c.f.s. (sub-critical flow)
3b.	**Emergency Spillway**	
	Type	Vegetated Earth with parabolic cross-section
	Crest Elevation	2634.2 feet NGVD
	Wetted Perimeter	100-125 feet
	Capacity with Reservoir at Minimum Dam Crest El. 2635.1 feet NGVD	110 c.f.s.
4.	**Principal Outlet Works**	
	Location	Near Right Abutment on North Dam
	Type	18" CMP W/Slide Gate at Inlet
	Outlet Elevation	2624.6 feet NGVD
	Conduit Length	Est. 80 feet
	Capacity with Reservoir at Minimum Dam Crest	16 c.f.s.

PERTINENT DATA
Continued

5. Irrigation Outlet Works

Location	Near Left Abutment on East Dike
Description	Buried Conduit to Very Small Reservoir Downstream
Conduit Type	8-inch-diameter asbestos-cement (reported)
Conduit Length	2000+ feet
Gate	8-inch Slide Gate in Wet Well at Dam
Capacity with Reservoir at Dam Crest	Insufficient information, but Negligible

6. Embankments

	North Dam	East Dike
Type	Rolled Earth	Rolled Earth
Minimum Crest Elevation		2635.1 feet NGVD
Crest Length	525 feet	1,400 feet
Crest Width	10 to 12 feet	3 to 12 feet
Hydraulic Height (crest to toe)	11 feet	7 feet
Upstream Slope	1V on 6H (variable)	1V on 6H (variable)
Downstream Slope	1V on 1.5H to 3H	1V on 2.5H

CHAPTER 1
BACKGROUND

1.1 INTRODUCTION

1.1.2 Authority and Scope

This report summarizes the Phase I inspection and evaluation of the Sands Reservoir Dam and Dike, owned by the Havre Irrigation Company.

The National Dam Inspection Act, Public Law 92-367 dated 8 August 1972, authorized the Secretary of the Army, through the Corps of Engineers to conduct safety inspections on non-federal dams throughout the United States. Pursuant to that authority, the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" in Appendix D, Volume 1 of the U.S. Army Corps of Engineers' Report to the United States Congress on "National Program of Inspection of Dams" in May, 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many federal and state agencies, professional engineering organizations and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

Where necessary the guidelines recommend a two-phase study procedure for investigation and evaluation of existing dam conditions so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) a limited investigation to assess the general safety condition of the dam.
(2) based upon an evaluation of the available data and a visual inspection.
(3) performed to determine if any needed emergency measures and/or if additional studies, investigations and analyses are necessary or warranted.
(4) not intended to include extensive explorations, analyses or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulic and hydrologic analyses and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations with the exception of situations of extreme emergency. In these cases the Corps may proceed with Phase II studies but only to the extent needed to answer serious questions relating to dam safety that cannot be answered otherwise. The two phases of investigations outlined above are intended only to evaluate project safety and do not encompass in scope the engi-

neering required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective work.

The responsibility for implementation of these Phase I recommendations rests with the dam owner and the State of Montana. It should be noted that nothing contained in the National Dam Inspection Act, and action or failure to act under this Act shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership and operation of the dam.

1.1.2 Purpose

The purpose of the inspection and evaluation is to identify current physical and operational conditions of the dam and appurtenances; and to determine if emergency measures and/or additional studies, investigations, and analyses are needed, so that corrections can be made in a timely manner by non-federal interests.

1.1.3 Inspection

The findings and recommendations in this report were based on hydrologic analyses and a visual inspection of the project. Original design and construction reports were not available.

It was not possible to determine who provided planning and engineering construction services for the project. Inspection procedures and criteria were those established by the Recommended Guidelines for the Safety Inspection of Dams (Ref. 1).

The inspection was conducted jointly by personnel from Christian, Spring, Sielbach & Associates and Northern Testing Laboratories, Inc., subcontractors. Personnel who participated in the field inspection and contributed to this report were:

CSSA- Bob B. Gemmell, Engineer, Team Leader
Alfred Cunningham, Hydraulics/Hydrology (report only)
Les Crawford, Civil Engineer

NTL- Robert Gillespie, Geotechnical Engineer (report only)
Bill Henning, Geologist
Gary Quinn, Geotechnical Engineer

Other personnel present and participating in the field inspection include:

MDNRC- Larry Tegg

Havre Irrigation Company - Howard Sterrett
Gordon Sands

This report has been reviewed by: the Havre Irrigation Company and the State of Montana and their written comments are enclosed in Appendix A.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

a. Location, Owner, and Purpose

Sands Reservoir is offstream of Bullhook Creek, an intermittent tributary of the Milk River. The reservoir straddles Sec. 18, T32N, R16E, and Sec. 13, T32N, R15E, MPM, in Hill County, Montana less than ½ mile south of Havre, Montana by road (Plate 2). Available information does not indicate who originally planned and constructed the project. However, it seems to be public knowledge that the Sands family played a major role in its construction in 1911.

The dam is owned by the Havre Irrigation Company. The Havre Irrigation Company operates the reservoir for irrigation purposes. There is some recreational use of the reservoir.

b. Description of Dam and Appurtenances

Sands Reservoir is impounded by two rolled earthfill structures. The North Dam is approximately 11 feet high and 525 feet long. The East Dike is about 7 feet high and 1,400 feet long (Plate 3). The reservoir contains approximately 850 acre-feet at minimum dam crest elevation 2635.1 feet NGVD, and approximately 600 acre-feet at primary spillway crest elevation 2632.7 feet NGVD. All elevations for this report are relative to the reservoir water surface assumed elevation 2630.0 feet NGVD taken during the inspection and the field survey performed for this report.

Reservoir discharges are through the spillway, an outlet works in the North Dam and an irrigation outlet under the East Dike. The emergency spillway is a well grassed natural saddle located at the southeast periphery of the reservoir. A concrete box structure is recessed in the emergency spillway with bottom elevation approximately 1.5 feet below the crest of the emergency spillway. An excavated channel within the emergency spillway forms an approach to the primary spillway control box which has flashboards for lake level control. The emergency spillway and low flow control channel exit to a small holding pond just east of the county road (Plate 2). The principal outlet works is an 18-inch diameter CMP with an inlet slide gate located near the right abutment of the North Dam. An 8-inch-diameter irrigation outlet pipe is located near the left abutment of the East Dike and is controlled by a gate located in a 36-inch-diameter concrete wet well within the dam crest. The buried 8-inch-diameter line discharges into a very small holding reservoir some 2000 feet downstream.

Reservoir levels are controlled mainly by limiting inflows through the 7 mile diversion channel from Beaver Creek to the southwest (Photo 13). A concrete diversion structure at Beaver Creek with an 18-inch slide gate allows discharges into the excavated diversion channel. The diversion channel is trapezoidal in section with 1V on 2H side slopes and is about 10 feet wide across its bottom. The channel banks have been breached in a few places for access roads to farmlands and the effective depth of channel is probably less than 5-feet. Surface drainage is prohibited from entering the diversion by an approximately 5-foot high waste berm on the uphill side of the excavated channel. Therefore the drainage basin is limited to the immediate perimeter of the reservoir. The drainage boundary encompasses 150 acres including the 100 acre reservoir.

c. Hazard Potential

Based on visual reconnaissance and engineering judgment, several residences would be flooded by a sudden breach of the North Dam. A sudden breach of the East Dike would cause flooding in a mobile home court immediately north of the dike. On the basis of the recommended inspection guidelines, Sands Reservoir is small in size and the downstream hazard potential is high (Category 1). The conclusions on probable damage are not supported with a dam breach analysis to determine possible flood heights that would be experienced in the areas downstream that could be affected by a sudden failure.

1.2.2 Regional Geology

The Sands Reservoir Dam is at the northern edge of the Bearpaw Mountains in north-central Montana. The area is characterized by gently rolling hills and small mountains.

"Approximately 11,500 feet of sedimentary formations were deposited in north-central Montana in Paleozoic, Mesozoic, and early Cenozoic time. This long interval of sedimentation was followed by intrusive igneous activity and uplift in the Bearpaw Mountains area in late early Eocene or in middle Eocene time. Large-scale gravity slides then carried the volcanic deposits and parts of the underlying sedimentary section away from the central uplift. Extensive rifting, tilting, and collapse of the sedimentary and volcanic rocks occurred in the slide sheets. The youngest volcanic rocks, of middle Eocene age, were subsequently deposited on tilted, older volcanic rocks. Erosion in post-middle Eocene time removed the distal portions of the volcanic fields, stripped away formations of any Eocene, Paleocene, and late Cretaceous age in the plains, and produced sediment and terrace deposits of Miocene to Pleistocene age. In Pleistocene time a Continental ice sheet advanced from the northwest and covered the western, northern and eastern sides of the Bearpaw Mountains with glacial deposits" (Ref. 1).

1.2.3 Seismicity

The site lies in Seismic Zone 2, a zone of generally moderate seismic risk as per the Corps of Engineers Guidelines (Ref. 6). A seismic coefficient of 0.05 is appropriate.

Preliminary seismic mapping by Algermissen and Perkins indicates there is a 90 percent probability that the horizontal acceleration in rock will not exceed 0.04g in a given 50-year period at the site.

1.2.4 Site Geology

The reservoir area is dominated by glacial till and glacial fluvial deposits produced by Pleistocene glaciation. The reservoir is in a natural low area, possibly a small kettle hole remnant. Tertiary volcanic deposits are present to the north and south of the reservoir and may underlie the alluvial sediments of post-middle Eocene time on the north side of the reservoir.

The abutment contact and foundation of the dam at the left abutment are silty and sandy clay glacial till. The foundation soils change to glacial fluvial soils, consisting of sorted silts, sands, and gravels, in the center and at the right abutment contact.

The abutments and foundation of the East Dike consist predominantly of glacial fluvial deposits of silts, sands, and gravels with some pockets of silty clay till.

The reservoir spillway cuts through reworked till and alluvial deposits of sands and clays in the southeast corner of the reservoir.

1.2.5 Design and Construction History

It is generally believed the dam was constructed by the Sands family in 1911. However, there are no plans, specifications, design or construction records available for the original construction.

In the late 1970's a mobile home court was constructed adjacent to the toe of the East Dike. The 8-inch-diameter irrigation outlet was extended under the court some 2,000 feet to a very small reservoir downstream. The court owner, Mr. Smith, reported that the ground water table is actually at natural ground level very near the East Dike during most of the summer months. He also indicated large lenses of silty clays and lenses of washed gravels were encountered during utility excavation for the court. No other information on the project history was available.

CHAPTER 2
INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

2.1.1 Spillways

a. Primary Spillway

The primary spillway is an open concrete structure with a 6-foot bottom width and 1.5-foot depth located in a natural saddle that serves as an emergency spillway for the project. The bottom elevation of the structure is at 2632.7 feet NGVD and it has 1.5 feet high sidewalls. Flashboards are placed in the structure to control lake levels. The excavated inlet and outlet channel for the structure has about a 10 foot bottom width and side slopes of 1V on 2H. Flows greater than 1.5 feet depth submerge the low flow control structure and spill into the emergency spillway.

b. Emergency Spillway

The emergency spillway is a well vegetated natural saddle located at the southeast rim of the reservoir about 300 feet from the south end of the East Dike (Plate 3). The parabolic shaped emergency spillway in profile has about 150 feet of level section which terminates at about elevation 2632.7 feet NGVD in an exit channel of rapidly broadening section at greater than critical slope (Plate 7). The low flow primary spillway discharges annually to this exit channel, however, there are no signs of serious erosion.

Spillway discharge capacity was computed using the methods in Ref. 8. The maximum discharge capacity with the reservoir at dam crest elevation 2635.1 feet NGVD was estimated to be 110 c.f.s. A discharge rating curve is shown on Plate 8.

2.1.2 Outlet Works

a. Principal Outlet Works

The principal outlet works is located approximately 75-feet from the right abutment on the North Dam (Plate 3). It consists of an 18-inch-diameter corrugated metal pipe (CMP) about 80-foot long through the embankment. Discharges are regulated by a slide gate mounted on the inlet and controlled by a handwheel on the dam crest (Photos 4 and 5 and Plate 5). Discharge through the conduit is estimated at 16 c.f.s with reservoir at minimum dam crest elevation 2635.1 feet NGVD. The inlet elevation is not known, however, the outlet invert is 2624.6 feet NGVD.

The principal outlet works discharges into a small irrigation channel. During maximum flows the small channel would probably overtop, and spill over onto fairly flat agricultural land that eventually drains to Squaw Creek (Photo 6). The gate was not operated at the time of inspection. However, it appeared in good condition and sealed well. The owner's representative present indicated the gate worked well and was used throughout the summer to control irrigation flows. The outlet of the conduit appeared to be in good condition with no signs of deterioration. The inlet and the gate were inundated and could not be inspected.

b. Irrigation Outlet

The small irrigation outlet is located near the left abutment of the East Dike, immediately upstream from a mobile home court (Plate 3). It reportedly consists of an 8-inch diameter asbestos-cement pipe. The line is buried for its entire 2,000 feet length to a very small reservoir or pond downstream and runs through a residential area (Photo 8). Discharges are controlled by a slide gate inside a 36-inch-diameter concrete vertical riser located at the centerline of the broadened dike crest (Plate 6). Reported inlet elevation is at about 2626 feet NGVD. Both the inlet and the outlet were submerged at the time of inspection and their condition and size could not be verified.

2.1.3 Freeboard

Routings indicate that although the dam is not overtopped during the probable maximum flood with a 50 c.f.s. inflow in the diversion channel (see Paragraph 2.2.4) freeboard does not exist with the recommended spillway design flood. At the time of inspection the reservoir was at an elevation approximately 2.7 feet below the primary spillway crest elevation 2632.7 feet NGVD. The vertical distance between the low point on dam crest and reservoir level at time of inspection was approximately 5.1 feet. The highest lake levels appear to be at elevation 2633.0 feet NGVD, 2.1 feet below the top of the dam. Anticipated wave heights are less than 2 feet. Although the dam could overtop during the PMF, the vertical distance between the normal reservoir level and the minimum crest elevation is considered adequate to prevent overtopping by wind generated waves.

2.2 HYDROLOGY

2.2.1 Physiography and Climatology

The Sands Reservoir is located at latitude 48° 32' longitude 109° 42' near the town of Havre, Montana (Plates 1 and 2). This off-stream storage facility receives water from a diversion from Beaver Creek for the purpose of meeting downstream irrigation demands. The site is located in what is commonly known as the northern Great Plains of Montana which is characterized by flat, treeless expanses, and large gently rolling hills.

The climate of this region of Montana is commonly considered Continental and therefore typical of the interior of a large land area. Weather in this region is highly variable with rapid changes brought on by the invasion of large air masses from the Gulf of Mexico, the South and Southwest, the North Pacific, and Polar Regions. Montana is in the westerly wind belt throughout the year with the result that much of its weather comes from the Gulf of Alaska. Temperature variation is extreme with highs at the Sands Reservoir site ranging in the upper nineties and winter lows down to about minus 30°F (Ref. 2). The average "freeze free" season at the Sands Reservoir site is about 110 days ranging from mid-May to mid-September. Average annual precipitation is 11.55 inches with heavy amounts occurring in the form of summer thunderstorms. Annual average lake evaporation at this site is 40 inches.

2.2.2 Reservoir Storage and Spillway Discharge

The Sands Reservoir has a storage of 600 acre-feet at the spillway crest elevation 2632.7 feet NGVD and 850 acre-feet at minimum dam crest

elevation 2635.1 feet NGVD, thereby providing approximately 250 acre-feet of surcharge storage. The combined spillway capacity (i.e. spillway plus low level outlet) is about 126 c.f.s. at reservoir elevation 2635.1 feet NGVD.

2.2.3 Estimated Probable Maximum Flood

The probable maximum flood (PMF) is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region.

The PMF for Sands Reservoir was developed using the HEC-1 Flood Hydrograph Dam Safety Computer Program (Ref. 5). Primary program input consisted of the 72-hour probable maximum precipitation (PMP) which was obtained for the study site from Ref. 3. The 24-hour 10-sq. mile PMP value was determined from Ref. 3 to be 21 inches. PMP values for duration of 1, 2, 3, 4, 5, 6, 12, 24, 48 and 72-hours were also determined from Ref. 3 and used to plot a depth-duration curve. This curve was used to find one-hour incremental PMP values which were subsequently arranged in a critical sequence according to Ref. 9. Total precipitation for the 72-hour period was found to be 23.52 inches and the maximum hourly value was 10.97 inches.

Because Sands Reservoir is an off-stream storage facility the contributing drainage area is extremely small (150-acres). As a result the maximum reservoir surface area (100-acres) covers about two-thirds of the drainage. Under these conditions it is reasonable to assume that the entire drainage behaves as a reservoir during the PMP and, therefore, no "time of concentration" for overland flow was computed here. Instead it was assumed that the total rainfall during each 10 minute storm interval (i.e. the total volume for 150-acres) enters the reservoir during that same time interval. Consequently, the unit hydrograph consists of a single value which converts rainfall during each 10 minute interval into reservoir inflow (c.f.s.).

Combination of the critical PMP sequence with the unit hydrograph ordinate resulted in the PMF inflow hydrograph to Sands Reservoir. It was also assumed that frozen soil conditions prevailed during the PMP resulting in an infiltration rate of "zero". At the time of the inspection the reservoir was being filled and channel flow was estimated at 110 c.f.s. From information gathered during the inspection it was estimated that normal summer irrigation flows would be less than 50 c.f.s. and maximum channel capacity is approximately 250 c.f.s. to 300 c.f.s. A constant inflow of 50 c.f.s. was assumed from the canal during the entire storm. The resulting PMF inflow volume to the reservoir was estimated to be 594 acre-feet.

2.2.4 Flood Routing

Routing of the estimated PMF hydrograph through Sands Reservoir was accomplished by means of computer program HEC-1 (Ref. 5). Initial reservoir surface elevation was assumed to be at primary spillway crest (El. 2632.7) at the onset of the PMF while initial inflow was assumed to be 50 c.f.s. Infiltration was taken to be zero for the entire storm and the modified puls method was used for reservoir routing.

Routing studies indicate that the Sands Reservoir will successfully pass the estimated PMF without overtopping provided that inflow from the diversion channel is less than 50 c.f.s. The maximum reservoir surface elevation during the flood was found to be 2634.96 feet NGVD compared to the minimum dam crest elevation of 2635.1 feet NGVD. Maximum spillway discharge during the PMF was 110 c.f.s.

It should be noted that the 50 c.f.s. inflow is considered to be a reasonable assumption although it is extremely difficult to make an exact judgment on this matter. For comparison purposes HEC-1 runs were also made with constant reservoir inflows of 100, 200, and 300 c.f.s. In all of these additional runs the reservoir level overtopped the dam. The conclusion is that Sands Reservoir will successfully pass the PMF provided the reservoir inflow during the PMF (from the diversion channel) does not exceed 50 c.f.s.

2.3 GEOTECHNICAL EVALUATION

The Sands Reservoir was constructed around 1911 by damming the outlets of a post-glacial drainageway. The drainageway is tributary to Bullhook Creek, an intermittent stream carrying surface runoff through Havre to the Milk River.

Records of foundation investigations, stability analyses, or plans and specifications are not available for the structure. There is no record or evidence of embankment instrumentation or monitoring.

2.3.1 North Dam Embankment

The dam, closing the drainageway at the northwest end of the reservoir, is approximately 525 feet long. Dam height ranges up to a maximum of approximately 11 feet at the outlet works near the right abutment. Crest width varies from 10 to 12 feet. There is approximately 2.1 feet of freeboard under normal operating conditions. The water level at the time of investigation was about 5 feet below the crest (Plate 4).

The profile survey done at the time of inspection indicates the dam crest is generally irregular as is the alignment. No cracking was observed on the crest, and there was no evidence of it being used for vehicular traffic. The embankment material appears to be a silty clay-gravel mixture.

The upstream slope is covered to a large extent by deciduous trees, shrubs, and native grasses (Photos 1 and 2). There is evidence of previous wave cutting of the upstream face near the high water line along the dam crest (Photo 3), which produced a bench and a vertical cut approximately 2 to 3 feet high. Below the bench, the upstream slope is about 1V on 6H (Plate 4). No evidence of cracking or recent settlement along the slope was observed. The downstream slope varies from 1V on 3H over most of the face, to 1V on 1.5H near the outlet works (Plate 4). No cracking or differential movement was observed along the slope. While no seepage through the embankment was noted, the ground beyond the downstream toe was wet. Scattered animal burrows were noted. A fairly dense cover of grasses protects the downstream slope.

The abutment contacts did not show any indication of cracking, differential movement, or erosion. There was some evidence of seepage beyond the downstream toe at the right abutment contact of the North Dam.

East Dike

The dike closes natural drainageways in the hummocky glacial topography along the east side of the reservoir (Plate 3). There is a trailer park immediately downstream, extending from the left abutment to about midpoint of the dike.

The dike is about 1400 feet long and has a maximum height of about 7 feet. Crest width is typically 12 feet, but it has been eroded by waves to a minimum width of 3 feet with a vertical cut of 2 to 3 feet, for a length of about 200 feet from the midpoint of the dike northward (Photos 7, 8 and 9). The observed reservoir level was lower than the downstream toe elevation (Plate 4).

The dike alignment is curved and somewhat irregular (Photo 10). The embankment materials appear to be clayey and silty sands. The dike carries vehicular traffic only in the left abutment area, where it has been widened by placing fill on the downstream side (Photo 7).

The upstream slope is covered with deciduous trees, grasses, and shrubs (Photos 9 and 10). Except for the wave cut area, the dike slopes are 1V on 6H upstream, and 1V on 2.5H downstream (Plate 4). A fairly dense grass cover protects the downstream slope. There is no evidence of cracking, recent settlement, or animal damage on the crest or slopes. No seepage was observed through the dike, but there are some localized wet areas immediately beyond the downstream toe (Photo 11).

The abutment contacts appear sound, with no evidence of seepage or differential movement.

2.3.2 Foundation Conditions, Seepage, and Drainage

The dam and dike have been formed by filling depressions in the undulating glacial topography at the site. These depressions or drainageways are usually poorly drained, with groundwater fluctuating seasonally to elevations near the ground surface.

North Dam

The foundation materials are glacial deposits consisting of clayey glacial till at the left abutment, grading to fluvial silts, sands, and gravels at the right abutment.

Poorly drained conditions exist along the drainageway downstream of the dam, as indicated by marsh grass vegetation and soft, wet soils at ground surface. Immediately downstream of the embankment toe, seepage waters were observed at the ground surface. It could not be ascertained whether this seepage was due to underflow or the generally poorly drained nature of the area. Although no seepage through the embankment was apparent, the tree-root system on the upstream slope provides a potential for channelization of seepage during periods of higher pool elevations.

The principal outlet works, discharging into a ditch to the broad, poorly drained valley downstream, is located near the right abutment (Photo 5). There is no significant erosion around the outlet conduit or along the ditch.

East Dike

The foundation materials are predominantly silts, sands, and gravels of glacial fluvial origin, with some areas of clayey glacial till.

The downstream area is poorly drained, where moist conditions and marsh vegetation were observed (Photo 11). This seepage could not be definitely traced to reservoir loss by underflow. Although no seepage was observed through the dike at the low pool elevation, potential seepage paths have been considerably shortened along the section where wave erosion has cut the dike. The tree-root system in the upstream slope is a potential path of seepage during periods of higher pool elevations.

An irrigation outlet works near the left abutment was inundated and it's inlet could not be visually inspected.

2.3.3 Stability

At the time of inspection there was no evidence indicating mass instability. However, this judgment is not supported by a stability analysis, and no data was available to make one. The 70 year longevity suggests the dam and dike are stable under current operating conditions. However, if lake levels were maintained at higher than normal levels for a period of time, the section in the East Dike that has been weakened by wave erosion would be judged to be marginally stable with development of a high phreatic surface and preferential seepage paths.

2.4 PROJECT OPERATIONS AND MAINTENANCE

2.4.1 Dam Maintenance Plan

Project maintenance inspections do not appear to have been made on a regular basis. No records or published maintenance plans were available for review. Maintenance has been performed by the operator as needed. Suggested maintenance items are contained in the recommendations (Sec. 3.2).

2.4.2 Reservoir

Pool levels fluctuate with the irrigation season requirements. Normal maximum pool elevation appears to be about 2633.0 feet NGVD. Minimum pool elevation is estimated to be at 2624.0 feet NGVD. Reservoir storage records were not available for review. There is no formal plan for reservoir operations. The water users visit the project almost daily during the irrigation season.

2.4.3 Warning Plan

There is no formal downstream warning plan in case of impending dam failure.

CHAPTER 3
FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of the dam, supplemented by analysis of engineering data for the project in terms of the Recommended Guidelines (Ref. 6) resulted in the following findings:

3.1.1 Size, Hazard Classification and Safety Evaluation

The 11-foot high dam and the 7-foot high dike impound about 850 acre-feet of water with the reservoir at minimum dam crest. In accordance with inspection guidelines, the Sands Reservoir Project is small in size and based on our visual inspection and engineering judgment, it has a high downstream hazard potential (Category 1). Therefore, the guideline's recommended spillway design flood (SDF) for this project is in the range of 50 to 100 percent of the PMF. Due to the high downstream hazard potential, we recommend the project safely handle 100% of the PMF. Reconnaisance level investigations, and routing of the estimated PMF developed for this study, show the project is conditionally capable of handling the full PMF without overtopping.

The overriding condition is that inflows to the reservoir through the diversion channel from Beaver Creek be less than 50 c.f.s. Channel flows greater than 50 c.f.s. during the PMF will cause the reservoir to overtop the dam. Due to breaches of the diversion channel upstream from the project, it is not possible to accurately determine potential channel flows during a flood event without a detailed survey and analysis, which is beyond the scope of work of this Phase I safety investigation.

Because the project is very sensitive to the diversion channel flows that may occur during the PMF, and potential stability problems would exist in sections of the East Dike with the reservoir at higher than normal levels for a prolonged period of time, Sands Dam project may not conform to the recommended guidelines. More detailed hydrologic and hydraulic routing studies are needed to provide a basis for development of diversion and reservoir operation plans to control maximum lake levels during the routing of the PMF.

3.1.2 Spillways

a. Primary Spillway

The primary spillway for the project is a concrete box structure located in the emergency spillway on the southeast rim of the reservoir. Lake levels are controlled by installing flash boards in the structure during the irrigation season. It was reported by Mr. Sterrett that unauthorized persons had in the past removed or placed the flashboards causing undesirable lake level fluctuations. The maximum lake level fluctuations controlled by the primary spillway is 1.5 feet.

b. Emergency Spillway

If lake levels should rise above 2634.2 feet NGVD, which is 1 foot below minimum dam crest elevation, water would spill over into the emergency spillway. There are no signs of this having occurred as maximum lake levels observed were estimated to be at elevation 2633.0 feet NGVD. The exit channel for the spillways is well lined with native grasses. Because of the bulk length provided by a 150 foot level section prior to a change in bottom slope where super-critical flow velocities may occur, there is little likelihood of a breach occurring in the spillway.

3.1.3 Outlet Works

a. Principal Outlet Works

The principal outlet is an 18-inch-diameter CMP with a slide gate at its inlet. The inlet was submerged at the time of inspection and its condition could not be visually determined. The slide gate was in a closed position at the time of inspection and appeared to be sealing properly. Overall, the principal outlet works appeared to be in good condition. Due to small size, a complete inspection of conduits was not made.

b. Irrigation Outlet Works

The small irrigation outlet is reportedly an 8-inch-diameter asbestos-cement conduit. A line from the reservoir empties into a 36-inch diameter vertical concrete pipe which serves as a wet well. The discharge line is controlled by a slide gate in the wet well. Visual verification of anything but the 36-inch vergical wet well was impossible due to high water. The gates, lift mechanisms and conduits should be thoroughly inspected at an early date.

3.1.4 Reservoir Storage and Discharge Capacity

The reservoir has a surface area of about 100-acres and a storage of 600 acre-feet at spillway crest elevation 2632.7 feet NGVD. Approximately 250 acre-feet of surcharge storage is available between the spillway crest and minimum dam crest elevation 2635.1 feet NGVD. The discharge capacity of the spillway, with the reservoir at minimum dam crest elevation 2635.6 feet NGVD is approximately 110 c.f.s. The principal outlet has a capacity of approximately 16 c.f.s. with reservoir at minimum dam crest.

3.1.5 Dam Embankments

The irregular crest profile and embankment cross section of both the North Dam and East Dike embankments probably reflect early construction techniques, blending of the embankment section into existing terrain, and probable lack of foundation preparation. However, the length of satisfactory service indicates that these matters are probably noncritical under current operating conditions.

North Dam

The upstream slope has undergone some wave erosion, but this process is somewhat controlled by the tree and shrub cover. However, the root system provides potential seepage paths under possible higher than normal pool elevations.

No seepage through the embankment was observed under the low pool elevation at the time of inspection. The area immediately beyond the downstream toe was wet, possibly the combined result of underflow and natural groundwater movement toward the drainageway.

The abutment contacts appeared stable.

No erosion of significance was evident around the outlet conduit or along the drainage channel downstream from the outlet.

East Dike

Previous wave erosion has reduced the crest width significantly for about a 200-foot length north of the midpoint. Under maximum pool eleva-

tion, potential seepage paths would be shortened in this area. The root systems might also enhance the potential for development of seepage paths.

No seepage was observed at the low pool elevation at the time of inspection. However, intermittent wet areas beyond the downstream toe were noted. Underflow and naturally poor drainage may contribute to this condition.

The abutment contacts appeared stable. The dike has been widened considerably near the left abutment.

3.1.6 Stability

Dam and Dike

Present operating conditions and past service indicate dam stability to be adequate. However, should operating conditions change, allowing development of steady state seepage conditions under prolonged higher than normal pool elevation, the likely development of preferential seepage paths could lead to erosion and possible sloughing on the downstream slopes. Insufficient information is available to analytically evaluate embankment stability. In accordance with the recommended guidelines, stability and seepage analyses should be conducted and placed on file for the project.

3.1.7 Operations and Maintenance

Normal pool elevations are maintained at or near the primary spillway crest by regulating inflow as well as outflow for irrigation. No formal operations plan for the reservoir exists. Maintenance is performed by the Havre Irrigation Company as necessitated. There is no formal warning plan for use in the event of impending dam failure.

3.2 RECOMMENDATIONS

Due to available surcharge storage the present project provides a degree of flood protection to the downstream area. The intent of report recommendations is to maintain or improve project safety, if feasible, without decreasing the existing flood protection.

1. Develop, implement, and periodically test an emergency warning plan for use in the event of dam distress.

2. Remove trees, large bushes, and their root systems from the constructed embankments. Replace and compact embankment materials to uniform slopes as needed.

3. Inspect the conduits and gates as soon as possible with the reservoir at a low level. Repair if needed.

4. Restore the east dike cross section to original dimensions for the eroded 200-foot length. Provide durable and effective wave erosion protection.

5. Have a qualified geotechnical engineer evaluate the dam embankments for stability and seepage with respect to recommended guideline criteria. Assessment of the phreatic surface through the dam may be based on piezometer readings or estimated embankment seepage conditions that could occur during a sustained high pool period. Place a record of this evaluation on file. Modify the dam sections as required for stability.

6. Perform more detailed hydrologic and hydraulic studies to better define the inflow hydrograph that would occur during the routing of the spillway design flood. Perform additional flood routings and instigate modifications in reservoir management and spillway capacity as the studies indicate.

7. Conduct inspections of Sands Dam and Dike at least every 5 years by qualified engineers experienced in earth dam design, construction, operation, and maintenance.

Prior to performing any remedial construction, contact the Montana DNRC, Dam Safety Section to insure compliance with all pertinent laws and regulations.

REFERENCES

1. Hern, Carter B., 1976, Geologic and Tectonic Maps of the Bearpaw Mountains Area, North-Central Montana, Department of the Interior USGS Map I-919.

2. Montana Department of Natural Resources and Conservation, "The Framework Report," Vol. I, October 1976.

3. National Weather Service, "Interim All Season Probable Maximum Precipitation Estimates, Missouri River Basin West of 105th Meridian," January, 1980.

4. Soil Conservation Service, SCS National Engineering Handbook, Section 4, Hydrology, 1972.

5. U.S. Army Corps of Engineers, "Flood Hydrograph Package (HEC-1)," Hydrologic Engineering Center; Davis, CA, Sept. 1978.

6. U.S. Army Corps of Engineers, Office the Chief of Engineers Report to the U.S. Congress, National Program of Inspection of Dams, Vol. 1, Appendix D, "Recommended Guidelines for Safety Inspection of Dams," Washington, D.C.; Department of the Army, May 1975.

7. U.S. Bureau of Reclamation, Design of Small Dams, Second Ed. 1974.

8. U.S.D.A. Soil Conservation Service, Engineering Division, Technical Release No. 39, Broad Crested Spillways, May, 1968.

9. U.S. Weather Bureau, "Hydrometeorological Report No. 43 - Probable Maximum Precipitation Northwest United States," November, 1966.

PHOTO 1

Sands Reservoir Looking North East

PHOTO 2

North (Main) Dam Crest

NOTE: Extensive Forestation on Upstream Slope

PHOTO 3

Erosion Bench On Upstream Slope of North Dam

PHOTO 4

Principal Outlet Works Gate Control

PHOTO 5

Downstream Face North Dam

NOTE: Outlet Works Exit Channel

PHOTO 6

Area Downstream of North Dam

PHOTO 7

Wide Crest Section on East Dike

NOTE: Mobile Home Court

PHOTO 8

Looking Downstream from Irrigation Outlet Culvert on East Dike

PHOTO 9

Minimum Width Crest Section on East Dike

PHOTO 10

Typical East Dike Crest Section

NOTE: Vegetation

PHOTO 11

Localized Wet Areas Along Downstream Toe of East Dike

PHOTO 12

Spillway Channel

Reservoir in Background

PHOTO 13

Diversion Channel ¼ Mile Upstream Looking Due South

NOTE: Road Distortion in Foreground Due to Wide Angle Lens

PROJECT LOCATION

MONTANA

CANADA
UNITED STATES

PLATE 1

SANDS DAM LOCATION MAP

0 5 10 20 30 40

SCALE IN MILES

Gravel Pit
R15E
R16E
Filtration Plant
1ST ST
Fairground
Cem
Gravel Pit
2537
BM 2491
WT
POI
CH
AVE
Lincoln-McKinley Sch
Park
Devlin Sch
5TH
Park
Hosp
ST
Central High Sch
WT
Water Tank
Hill
8
BM 2494
1ST
Jr High Sch
HAVRE
12
7TH ST
Highland Cem
Cem
AVE
10TH ST
5TH
WT
Athletic Field
Park
Park
11TH ST
Highland Park Sch
2602
WILSON AVE
MCKINLEY AVE
New Sunnyside Sch
Northern Montana College
2593
13TH ST
17TH ST
LANDING STRIP
2601
2605
High Sch
Park
DAM
DIKE
13
18
2530
Gravel Pits
Bullhook
Sands Lake
2627
2634
DRAINAGE BASIN
2626
2698
ROAD
24
19
20
2692
CREEK
2695
2712
2757
2677
BEAVER
25
Squaw Butte
30

PLATE 2
SANDS DAM DRAINAGE MAP

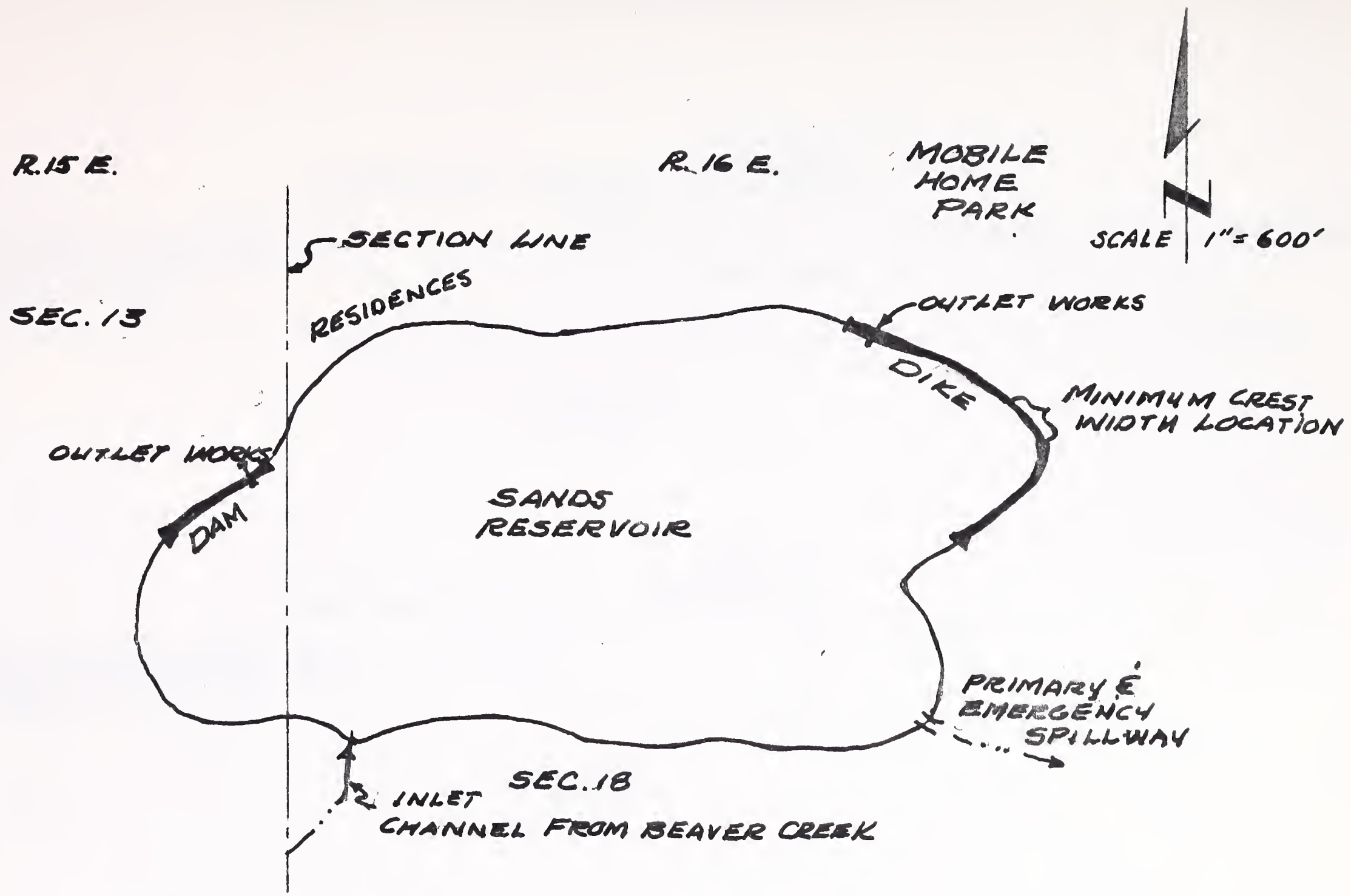
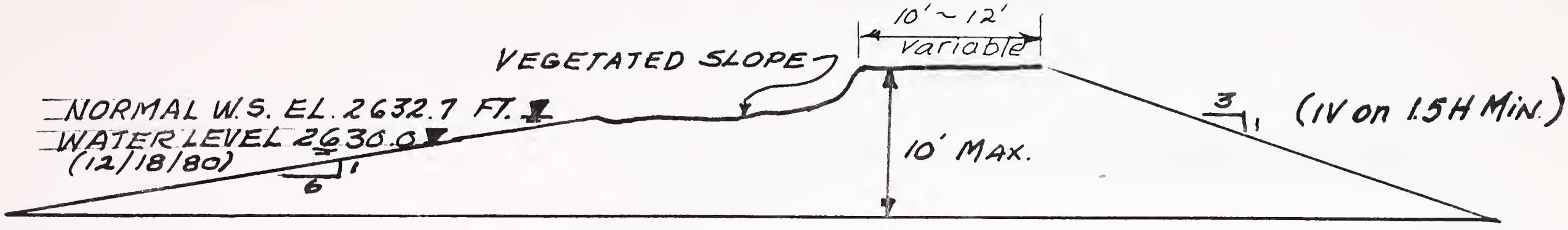
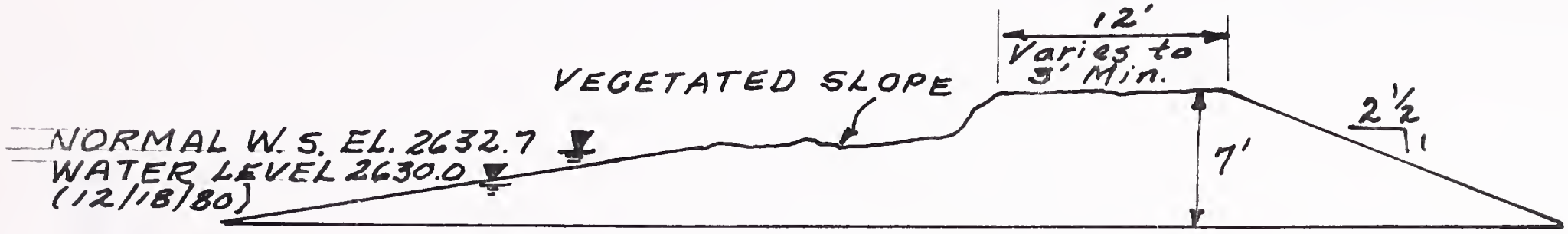


PLATE 3
SANDS DAM
SITE PLAN

APPROX. TYPICAL CROSS SECTIONS

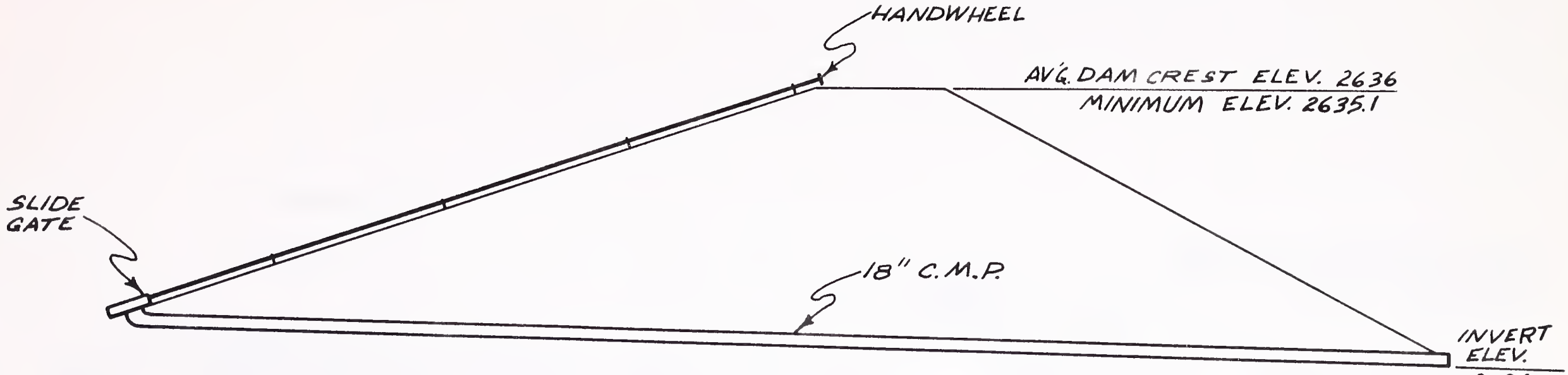


DAM
N.T.S.



DIKE
N.T.S.

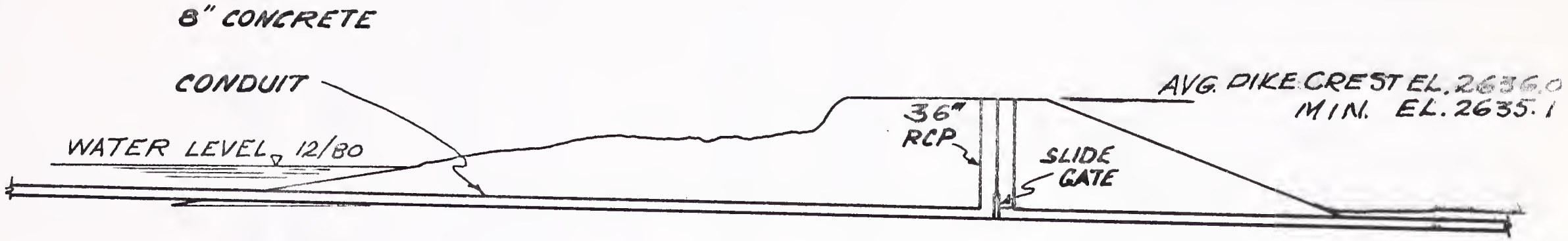
PLATE 4
SANDS DAM
DAM SECTIONS



NOT TO SCALE

PLATE 5

SANDS DAM
OUTLET WORKS
ON DAM



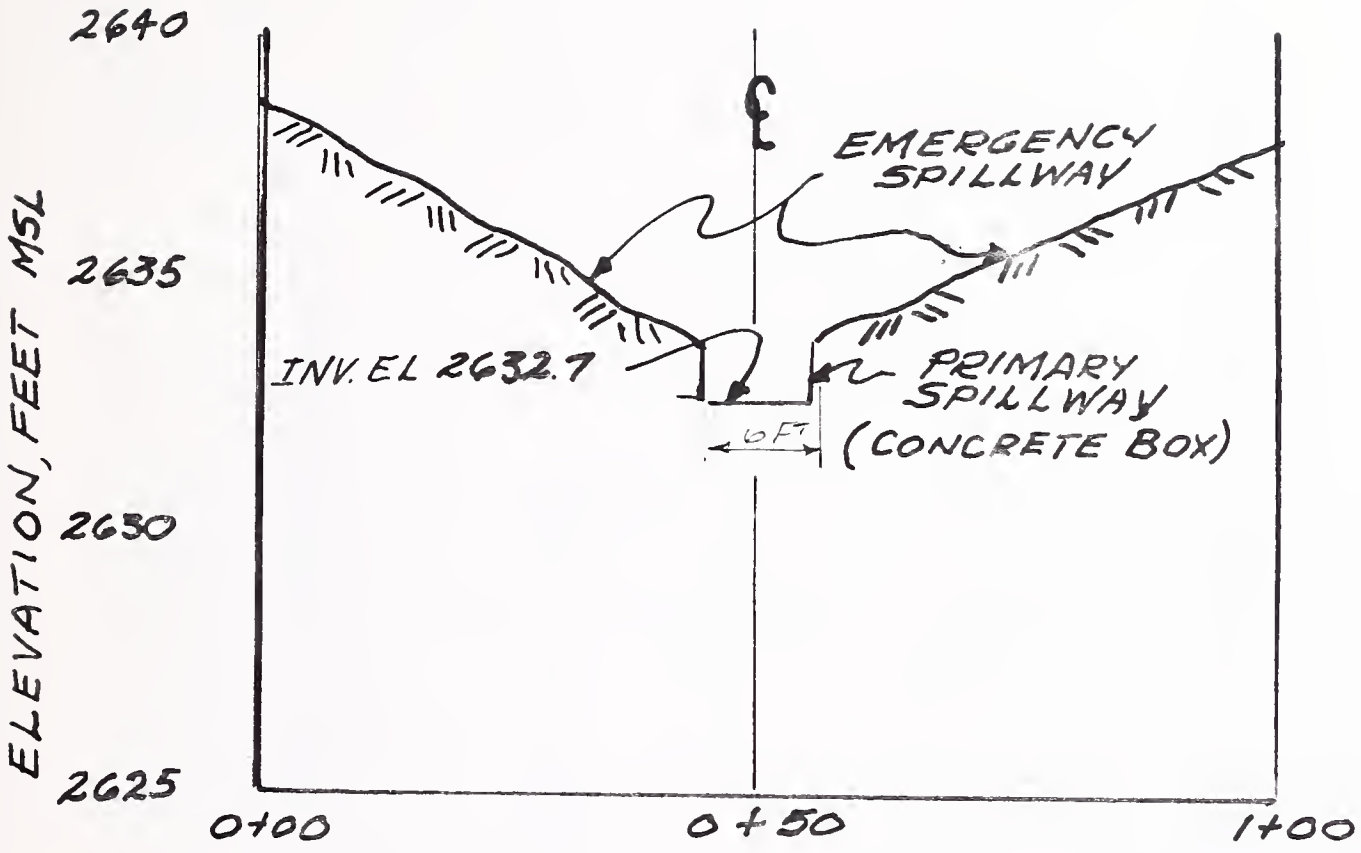
NOT TO SCALE

PLATE 6

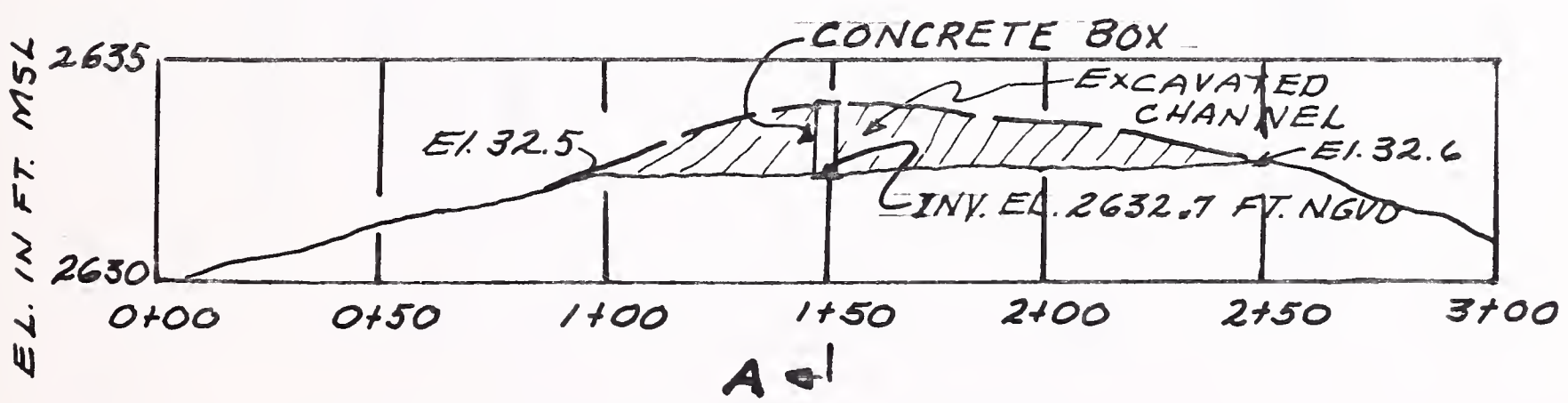
SANDS DAM

OUTLET WORKS

ON DIKE



SECTION A-A

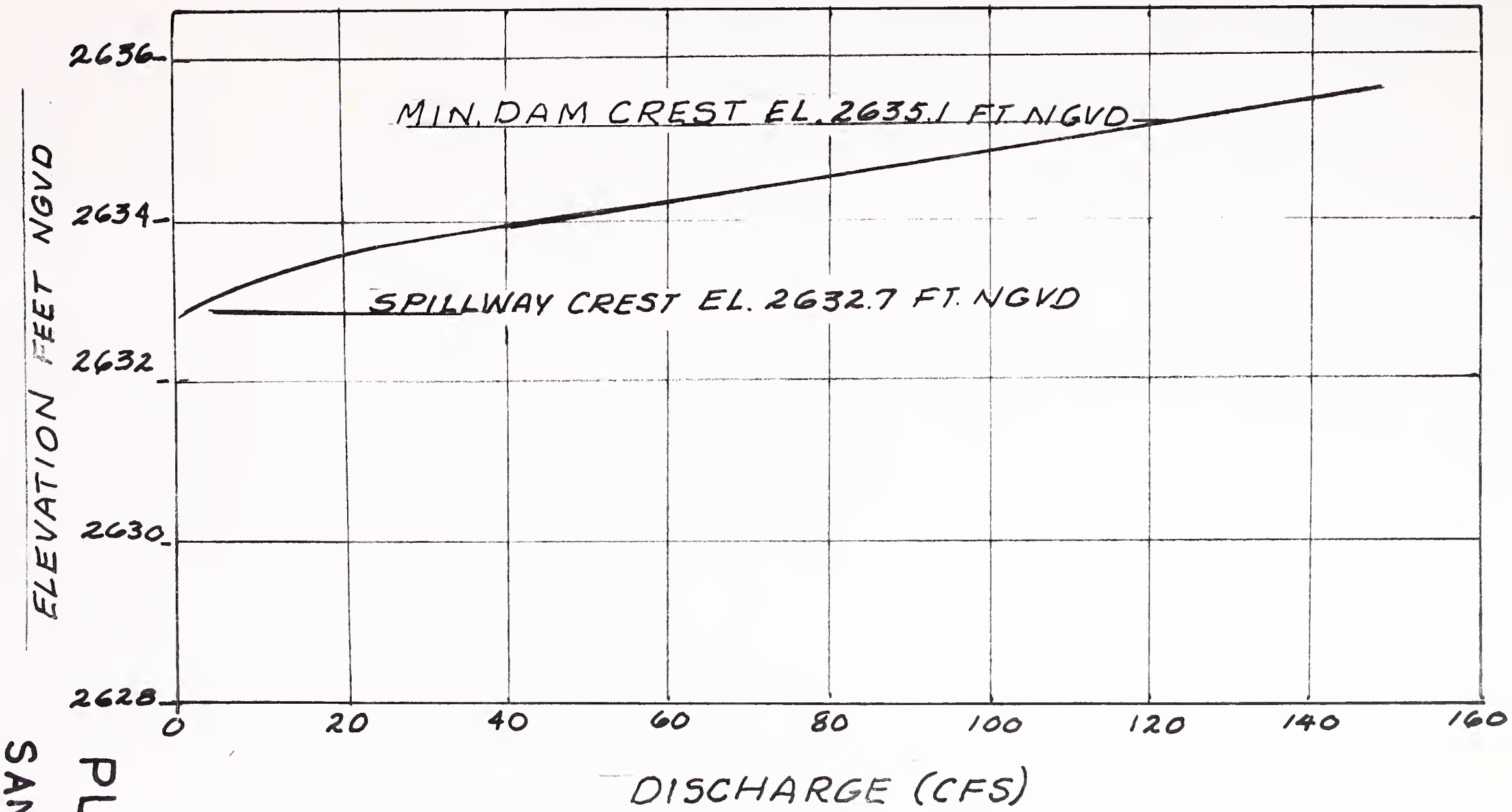


SPILLWAY PROFILE

PLATE 7

SANDS DAM

SPILLWAYS



PRIMARY AND EMERGENCY SPILLWAYS

SANDS DAM

RATING CURVE

PLATE 8

APPENDIX A

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

TED SCHWINDEN GOVERNOR

32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872 ADMINISTRATOR
(406) 449-3962 WATER RIGHTS BUREAU
(406) 449-2872 WATER SCIENCES BUREAU
(406) 449-2864 ENGINEERING BUREAU
(406) 449-2872 WATER PLANNING BUREAU

HELENA, MONTANA 59620

June 26, 1981

Ralph Morrison
Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Washington 98124

Dear Mr. Morrison:

The Department of Natural Resources and Conservation has reviewed the final draft report on the Sands Reservoir Dams, MT-3668 and MT-3773. We concur with the findings and recommendations in the report and feel that the report satisfies the criteria for the Phase I investigation. Our comments have been discussed with your staff and we understand that they will be incorporated into the final report.

Thank you for the opportunity to review and comment on the final draft report for this project.

Sincerely,

Richard L. Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau

R:LT:lz

Havre Irrigation Co.
Box 1484 - Havre, Mt. 59501

30 June 1981

Project Engr. Sidney Knutson
Asst. Chief, Engineering Div.
Seattle Dist. Corps of Engineers, USA
P. O. Box C-3755
Seattle, Wn. 98124

Dear Mr. Knutson:

Thank you for the four copies of your inspection report on Sands Reservoir Dam which was inspected by your group 17 December 1980. These copies have been given to our board of Directors and they have studied it carefully. Plans to implement your recommendations are under consideration.

As you suggest we will contact the DNRC before taking action.

Sincerely,

H. J. Clack

H. L. Clack
Sec.-Treasurer